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RADIOISOTOPE EXPERIMENTS IN HIGH SCHOOL BIOLOGY, AN ANNOTATED SELECTED BIBLIOGRAPHY.

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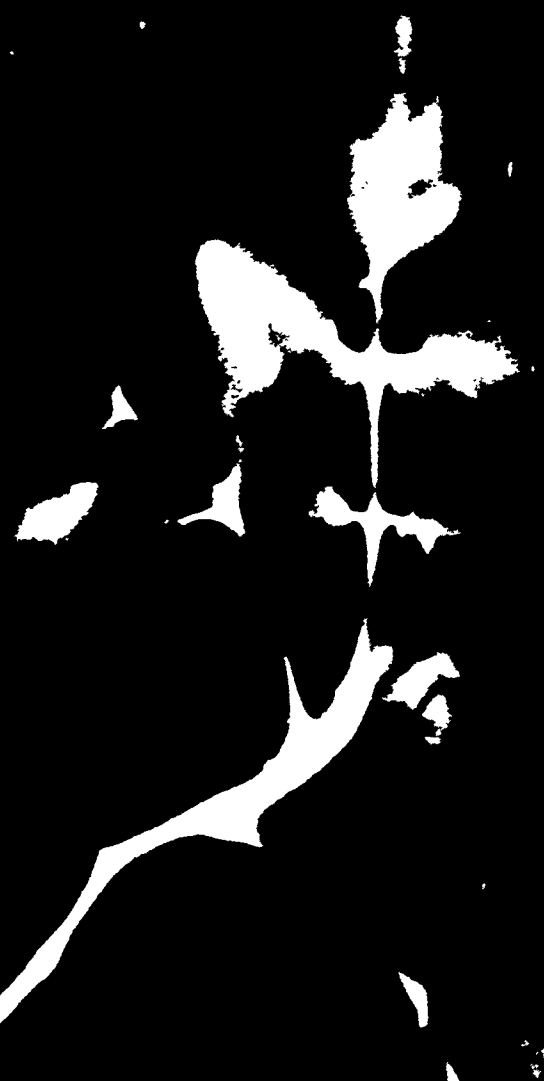
SELECTED REFERENCES ON THE USE OF RADIOISOTOPES IN BIOLOGY ARE CONTAINED IN THIS ANNOTATED BIBLIOGRAPHY FOR SECONDARY SCHOOL STUDENTS. MATERIALS INCLUDED WERE PUBLISHED AFTER 1960 AND DEAL WITH THE PROPERTIES OF RADIATION, SIMPLE RADIATION DETECTION PROCEDURES, AND TECHNIQUES FOR USING RADIOISOTOPES EXPERIMENTALLY. THE REFERENCES ARE LISTED IN ORDER OF THEIR VALUE TO A TYPICAL HIGH SCHOOL BIOLOGY PROGRAM IN TERMS OF VARIETY, FLEXIBILITY, AND APPLICABILITY. EXPERIMENTS IN EACH REFERENCE ARE CLASSIFIED AS BASIC OR BIOLOGICAL. SPECIAL TECHNIQUES OR MATERIALS REQUIRED IN THEIR COMPLETION ARE INDICATED. SOURCES OF RADIOISOTOPE EXPERIMENTS FOR HIGH SCHOOL CHEMISTRY AND PHYSICS, A LIST OF GENERAL READINGS IN NUCLEAR SCIENCE, AND A LIST OF SUPPLIERS OF RADIOISOTOPES ARE INCLUDED. THIS DOCUMENT IS AVAILABLE FREE FROM THE UNITED STATES ATOMIC ENERGY COMMISSION, P. O. BOX 62, OAK RIDGE, TENNESSEE 37830. (AG)

Radioisotope Experiments in High School Biology

An Annotated Selected Bibliography



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Radioisotope Experiments in High School Biology

An Annotated Selected Bibliography

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Division of Nuclear Education and Training/Division of Technical Information

Contents

Introduction

A student cannot hope to use radioisotopes or to comprehend the radiation aspects of biology without a fundamental understanding of the properties of radiation, simple radiation-detection procedures, and the techniques of using radioisotopes experimentally. Therefore this bibliography was prepared to help the interested student accomplish these prerequisites to the successful use of radioisotopes in biology. The books chosen for this bibliography are those which include experiments that will provide the student with the opportunity to learn the basic principles and skills, to become acquainted with the significant scientific facts, and to investigate a variety of biological problems.

For the convenience of the user, only experiments easily available are included since it is hoped that this reference guide will serve to stimulate the use of laboratory exercises. Emphasis is placed on the more recent publications, those printed since 1960, although significant materials were printed in the late 1950's.

The ten selected references are listed in the order of their value to a typical high school biology program in terms of variety, flexibility, and applicability. For each reference information about the contents, purpose, applicability, etc., is noted. Also, experiments are categorized, and the techniques or the materials used are indicated.

One of these ten references is a set of teaching materials called *Atomikits*. Although the *Atomikits* are not a conventional kind of reference, they are included because they provide a unique approach to instruction in radioisotope techniques. The *Atomikits* are a series of simple and practical radioisotope experiments, each contained in a package complete with discussion, full directions, and required materials.

This booklet is an abridged form of a similar, though more extensive, bibliography, *Radioisotope Techniques for Instruction in the Biological Sciences*, which was prepared for both high school and college instruction. The Division of Nuclear Education and Training of the United States Atomic Energy Commission encouraged and financially assisted Montgomery Junior College in the preparation of both bibliographies.

Selected Sources of Radioisotope Experiments in Biology

RADIOACTIVITY: FUNDAMENTALS AND EXPERIMENTS 1

Sister Mary Hermias and Sister Mary Joecile (Holt, Rinehart & Winston, Inc., 383 Madison Avenue, New York, N. Y. 10017. 1963. 209pp. $1.72)

This laboratory manual consists of two main sections: Part I is devoted to fundamental principles of radioactivity and to safety measures for handling radioisotopes. Part II presents 51 laboratory experiments, 12 of which apply to the biological sciences at the high school level. Appendixes provide information on procedures for ordering and handling radioisotopes, a list of suppliers of equipment and accessories, and a set of guiding principles for the use of animals in radiation experiments.

Basic Experiments

Electroscope-type Dosimeter, Exp. 4, p. 44.

Counting-rate Plateau of a Geiger-Müller Tube, Exp. 5, p. 47.

Efficiency of a Geiger Counter, Exp. 6, p. 51 (^{32}P; beta standard).

Scintillation Counter, Exp. 9, p. 58 (characteristics; operating curve).

General Techniques of Autoradiography, Exp. 11, p. 64.

Inverse Square Law, Exp. 13, p. 70 (end-window G-M tube; ^{32}P; ^{60}Co).

Absorption of Beta Radiation, Exp. 15, p. 78 (G-M tube; ^{32}P; aluminum squares).

Absorption of Gamma Rays, Exp. 16, p. 82 (scintillation detector; lead absorbers; ^{60}Co or ^{131}I).

Determination of Half-life, Exp. 20, p. 94 (G-M tube; ^{131}I or ^{32}P).

Diffusion in Liquids, Exp. 26, p. 109 (G-M counter; ^{22}Na solution).

Separation by Paper Chromatography and Autoradiography, Exp. 35, p. 127 (^{131}I thyroid extract).

Effects of Fallout, Exp. 39. p. 138 (radioactivity in milk due to fallout).

Experiments in Biology

Absorption of Phosphorus and Iodine by Plants, Exp. 40, p. 140 (uptake in tomato plants checked with G-M counter and autoradiography).

Translocation of Phosphorus-32 in Plants, Exp. 41, p. 144 (absorption via leaf; autoradiography).

Germination and Growth of Seedlings, Exp. 42, p. 146 (absorption of ^{32}P; autoradiography).

Absorption of Radioactive Phosphorus by Bacteria, Exp. 44, p. 152 (autoradiography).

Absorption and Assimilation of Phosphorus-32 from Water by Fish, Exp. 45, p. 155 (G-M counter; autoradiography).

Distribution of Phosphorus in an Animal Body, Exp. 46, p. 158 (white mice; organ sampling by wet-ashing).

Absorption of Phosphorus by Red Blood Cells, Exp. 47, p. 161 (rabbit red blood cells; *in vitro*).

Calcium Exchange in Bone, Exp. 48, p. 164 (white mice; activity of bone ash detected with G-M tube).

Uptake of Iodine-131 by the Thyroid Gland, Exp. 49, p. 166 (normal rate of selective absorption from blood; effect of drugs and conditions on rate of uptake in white rats).

Determination of Blood Volume, Exp. 50, p. 170 (*in vivo* measurement by isotope dilution).

Absorption of Carbon Dioxide by Plants, Exp. 51, p. 173 ($Na_2C^{14}O_3$; measurement of radioactivity with G-M counter and autoradiography; chromatographic separation of amino acids).

2 LABORATORY EXPERIMENTS IN RADIATION BIOLOGY

Edward I. Shaw [U. S. Atomic Energy Commission, Washington, D. C. April 1965. 81pp. $0.50. Available as TID-18616(Rev.) from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402]

This laboratory manual provides some experiments useful at the advanced high school level for familiarizing students with several aspects of radiation biology. It includes 37 experiments, some of which demonstrate special techniques and fundamental principles as well as tracer applications and the biological effects of radiation. There is a brief introductory section on radiological safety; the appendixes include lists of references on radiation biology and valuable information on licensing of by-product materials and suppliers of radiation-detection equipment, accessories, and radioisotopes.

Basic Experiments

Sample Preparation, p. 3 (general techniques).
Preparation of a Card Mount, p. 6 (general directions).
Electroscope and Inverse Square Law, p. 11 (gamma source; dose rates at varying distances).
Geiger Counting, p. 14 (operating potential; plateau).
Relative Range of Radiation in Absorbers, p. 24 (^{137}Cs; aluminum filters).
Measurement of Short Half-life, p. 26 (^{24}Na, ^{131}I, or ^{32}P; Ra D+E reference source).
Radiochromatography, p. 39 (^{32}P, ^{60}Co, or ^{45}Ca; G-M counter).

Experiments in Biology

Translocation of Radioelements in Plants as Demonstrated by Autoradiography, p. 37 (bean or tomato plants; ^{45}Ca, ^{32}P, or ^{59}Fe).
Photosynthesis with $C^{14}O_2$ and Autoradiography, p. 41 ($BaC^{14}O_3$; coleus plant).
Radiochromatography: Carbohydrate and Amino Acid Metabolism, p. 43 (radioactive plant; amino acid standards; chromatography chamber).
Deposition and Distribution of Phosphorus-32 in the Rat, p. 46 (^{32}P; wet-ashing).
Uptake and Elimination of Iodine-131 in the Rat, p. 48 (scintillation counting).
Metabolism of Iodine-131 Labelled Thyroxine in Rats, p. 49 (scintillation counting).

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EXPERIMENTS IN NUCLEAR SCIENCE

Grafton D. Chase, Stephen Rituper, and John W. Sulcoski (Burgess Publishing Co., 426 South Sixth Street, Minneapolis, Minnesota 55415. 1964. 167pp. $3.50)

This laboratory manual presents selected experiments in the basic techniques and principles of using radioisotopes. It includes a total of 54 experiments, 7 of which apply to biology at the high school level. Its companion, *Teacher's Guide for Experiments in Nuclear Science* ($2.45), covers most facets of student experiments and radioisotope techniques which may be unfamiliar to some teachers.

Basic Experiments

Sample Preparation 1, Exp. 3, p. 6 (card mounts; use of micropipette, propipetter, planchets with nonradioactive solution).

Sample Preparation 2, Exp. 4, p. 8 (source preparation using ^{204}Tl, RaDEF, or ^{36}Cl).

Plotting a Geiger Plateau, Exp. 5, p. 9.

Background, Exp. 6, p. 13.

Geiger Tube Efficiency, Exp. 8, p. 17 (^{204}Tl; ^{133}Ba; ^{14}C).

Half-life, Exp. 20, p. 48 (^{131}I or ^{32}P; G-M tube and scaler).

Autoradiography, Exp. 24, p. 62.

Inverse Square Law, Exp. 34, p. 93.

Absorption of Beta Particles, Exp. 35, p. 96 (^{204}Tl; G-M tube).

Absorption of Gamma Rays, Exp. 38, p. 104 (^{60}Co or ^{137}Cs; G-M tube).

Experiments in Biology

Absorption of Phosphate by a Plant, Exp. 26, p. 71 (uptake via root; detection of leaf activity with G-M tube).

Distribution of Phosphate in a Plant, Exp. 27, p. 74 (uptake via roots; detection of activity by autoradiography).

Nonroot Feeding of Plants, Exp. 28, p. 76 (absorption of ^{32}P via leaf; detection of activity with G-M tube and autoradiography).

Translocation of Phosphate in Stems, Exp. 29, p. 77 (transfer of ^{32}P from stem; detection of activity by G-M tube).

Absorption of Phosphorus by Frogs, Exp. 30, p. 79 (organ sampling by wet-ashing).

Absorption of Phosphorus by Fish, Exp. 31, p. 81 (organ sampling by wet-ashing).

Blood Volume, Exp. 32, p. 83 (^{51}Cr; isotope-dilution technique).

LABORATORY EXPERIMENTS WITH RADIOISOTOPES FOR HIGH SCHOOL SCIENCE DEMONSTRATIONS

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Samuel Schenberg, Editor (U. S. Atomic Energy Commission, Washington, D. C. July 1958. Rev. 59pp. $0.35. Available from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402)

This manual was especially adapted for use by teachers and students in high school. The appendixes provide information concerning the nature and properties of radioisotopes, the operation and construction of a Geiger-Müller counter, and the safe handling of radioisotopes.

Basic Experiments

Operating the Geiger Counter, Exp. 1, p. 1 (characteristic curve; operating voltage).

Geometric Efficiency, Exp. 2, p. 4 (calibrated RaDEF source).

Inverse Square Law, Exp. 4, p. 7 (gamma source; G-M counter).

Absorption of Beta Radiation, Exp. 5, p. 9 (G-M counter; ^{32}P; aluminum squares).

Absorption of Gamma Radiation, Exp. 6, p. 11 (^{131}I; G-M counter; lead plates).

Half-life, Exp. 9, p. 18 (^{131}I; G-M counter).

Experiments in Biology

Translocation of Radioactive Phosphorus in Celery Stalks, Exp. 14, p. 26 (G-M counting; autoradiography).

Translocation of Radioactive Phosphorus in Tomato Plants via the Roots, Exp. 15, p. 27 (G-M counting).

Translocation of Radioactive Phosphorus Upward and Downward in the Geranium Plant via the Stem, Exp. 16, p. 29 (G-M counting).

Removal of Radioactive Phosphorus from Water by Goldfish, Exp. 17, p. 30 (G-M counting of organs; autoradiography of skeleton).

Absorption of Radioactive Phosphorus by Yeast, Exp. 18, p. 31 (G-M counting; autoradiography).

Absorption of Radioactive Phosphorus by Bacteria, Molds, and *Drosophila*, Exp. 19, p. 35 (G-M counting; autoradiography).

Preparation of Autoradiographs, Exp. 20, p. 35 (fish skeleton; leaf; molds; bacteria; *Drosophila;* G-M counting; autoradiography).

5 ELEMENTARY EXPERIMENTS IN RADIATION BIOLOGY

Alison P. Casarett and Thomas P. Davis (University of Rochester, Rochester, New York. 1963. 63 pp. $1.50. Available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Va. 22151)

Laboratory experiments suitable for introducing simple radiation-detection procedures and for illustrating different aspects of radiation biology at the high school and undergraduate college level are given. Also included is an excellent section on autoradiographic techniques.

Basic Experiments

Operation of G-M Counter Scaler Systems, p. 3 (design features; operating characteristics; counting losses; resolving time).

Absorption and Energy of Beta Particles, p. 17 (^{32}P absorption curve; range determination: Feather method).

Attenuation of Gamma Rays, p. 25 (lead and aluminum absorbers).

Half-life Determination, p. 27 (^{131}I and unknown; G-M tube with scaler).

Isotope-dilution Principle, p. 32 (^{131}I standard in "unknown" volume of water).

Experiments in Biology

Uptake of Radioisotopes by Germinating Radish Seeds, p. 38 (^{32}P; ^{131}I).

Uptake of Phosphorus-32 by Tomato Plant, p. 39 (uptake of solution via root system).

Absorption of Phosphorus-32 by Yeast, p. 44 (uptake; effect of a toxic substance).

Uptake of Radioactive Phosphorus by Goldfish, p. 46 (organ sampling; autoradiography).

BIOLOGICAL SCIENCE: MOLECULES TO MAN

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Biological Sciences Curriculum Study American Institute of Biological Sciences (Houghton Mifflin Co., 2 Park Street Boston, Mass. 02100. 1963. 846pp. $7.96).

This book (BSCS blue version) is designed for the majority of high school biology students. In the BSCS approach to biology, emphasis is placed on laboratory work. Students examine materials, conduct experiments, and investigate problems. Some of the investigations in this book (those listed below) are directed toward the use of radioisotopes in solving typical biology problems.

Basic Experiments

Physical Properties of Radioactive Materials, Invest. 58, p. L 118

Effect of Radioactivity on Photographic Film

Detection of Radioactivity with the Geiger Counter

Effect of Distance from a Source of Radiation

Rate of Decay of Radioactive Atoms

(^{32}P; G-M counter; autoradiography).

Experiments in Biology

Tracing a Food Chain, Invest. 60, p. L 122 (^{32}P transfer from aquarium plants to snails and fish; G-M counting).

Transport of Phosphate in Plants, Invest. 61, p. L 123 (comparative uptake of ^{32}P via leaf and root; autoradiography).

Accumulation of Phosphate in an Animal, Invest. 62, p. L 124 (^{32}P uptake in frog; organ sampling with autoradiography).

ADVENTURES IN BIOLOGY

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Board of Education of the City of New York (February 1962. 289pp. $1.50. Available from Publications Sales Office, 110 Livingston Street, Brooklyn, N. Y. 11201)

This book is the result of a curriculum experiment to introduce high school students to problems and procedures of modern scientific research in biology. Six areas are treated, the last of which pertains to radioisotopes in biology.

Basic Experiments

What Is the Half-life of a Particular Radioactive Element? Proj. 192, p. 222 (G-M counter; ^{131}I).

How Does the Intensity of Radiation Vary with the Distance from the Source? Proj. 193, p. 223 (G-M counter).

To What Extent Are Gamma Rays Absorbed by Thin Lead Plates? Proj. 194, p. 224 (^{131}I; G-M counter).

Experiments in Biology

At What Rate Does Radioactive Phosphorus Translocate in Tomato Seedlings? Proj. 195, p. 225 (G-M counter).

To What Extent Will a Small Fish Take Up Radioactive Phosphorus from the Water? Proj. 196, p. 226 (G-M counter; autoradiography).

To What Extent Do Insects, and Other Small Animals, Absorb Radioactive Phosphorus? Proj. 197, p. 227 (fruit flies; G-M counter; autoradiographs).

How May the Half-life of Phosphorus-32 Be Used to Establish When Plants Became Radioactive? Proj. 198, p. 228 (house plant; G-M counter).

8 INTRODUCTORY COURSES IN NUCLEAR SCIENCE

Baird-Atomic, Inc., Atomic Accessories Division (1963–1965. Student manual and teacher's manual, $2.50 each. Available from Sales Office, 33 University Road, Cambridge, Mass. 02138)

The *Atomette*, *Minilab*, and *Autoradiography* manuals are designed to accompany commercially prepared basic nuclear science teaching units. The student experiment manuals provide introductory background and theory as well as from five to seven simple experiments demonstrating fundamental principles of radioactivity with some applications to biology. The companion teacher's manuals include background information, laboratory hints, and sample data. Each manual is available individually, and

the purchase of instruments and accessories is not required.

Basic Experiments

Background Radiation, *Atomette* exp. 1, p. 8 (rate meter; luminous-dial watch).

Effect of Distance upon Radiation, *Atomette* exp. 2, p. 9 (rate meter).

Absorption of Radiation, *Atomette* exp. 3, p. 10 (rate meter; assorted absorbers).

Half-life, *Atomette* exp. 4, p. 12 (rate meter; ^{32}P or ^{131}I).

Geiger Plateau, *Minilab* exp. 1, p. 10 (rate meter; beta source).

Inverse Square Law, *Minilab* exp. 3, p. 15 (rate meter; beta–gamma source).

Absorption of Beta Particles, *Minilab* exp. 4, p. 17 (rate meter; beta source; aluminum and cardboard absorbers).

Absorption of Gamma Rays, *Minilab* exp. 5, p. 19 (rate meter; beta–gamma source; lead absorbers.).

Half-life, *Minilab* exp. 6, p. 20 (rate meter; unknown radioactive source).

Detection of Fallout, *Autoradiography* exp. 4, p. 14.

Radiography, *Autoradiography* exp. 5, p. 16 (X-ray film; ^{32}P).

Experiments in Biology

Radioisotopes as Tracers, *Atomette* exp. 5, p. 14 (rate meter; tomato plants; ^{32}P).

Absorption of Phosphorus by Plants, *Autoradiography* exp. 1, (tomato or bean plant; ^{32}P; X-ray film).

Absorption of Phosphorus by Goldfish, *Autoradiography* exp. 2, p. 11 (^{32}P; X-ray film).

Absorption of Phosphorus by Yeast, *Autoradiography* exp. 3, p. 13 (^{32}P; X-ray film).

NUCLEAR SCIENCE TEACHING AIDS AND ACTIVITIES 9

John H. Woodburn (May 1959. 73pp. Available from the Office of Civil Defense, Training and Education, Washington, D. C. 20310)

This source book includes a variety of activities that could be adapted to laboratory and demonstration teaching. The

fundamental principles of radioactivity are clearly presented. This book describes some procedures for basic laboratory work in nuclear science or for student projects in high school biology, chemistry, or physics. Some accounts of student research with radioisotopes are included.

Experiments in Biology

How Large Doses of Beta Radiation Affect Fruit Fly Offspring, Student Project, p. 25 (^{32}P; G-M counter; mutations studied).

Plant Absorption, Experiment, p. 31 (autoradiography).

Animal Absorption, Experiment, p. 33 (Part I: ^{32}P; goldfish; autoradiography. Part II: ^{32}P; earthworms; frog; G-M counting; autoradiography. Part III: aquatic animals; ^{131}I; ^{22}Na; ^{32}P; ^{35}S; G-M counting; autoradiography).

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ATOMIKITS: EXPERIMENT KITS

Atomic Corporation of America, 7901 San Fernando Road, Sun Valley, Calif. 91352.

Atomikits are commercially prepared experiment kits; radioisotopes are used in experiments designed for high school biology courses. Each kit is complete with an introductory discussion, precise directions, and materials for student performance of the exercises. Each kit is individually priced.

Experiments in Biology

Metabolism of Phosphorus in a Goldfish, Atomikit 2, $5.95 ($^{32}P$ uptake; autoradiography).

Transport of Phosphate in Plants, Atomikit 3, $5.95 (translocation of ^{32}P; autoradiography).

Production of Radioactive Bacteria, Atomikit 4, $5.95 ($^{32}P$ uptake from bacterial medium; autoradiography).

Radioactive Fallout, Atomikit 5, $2.95 (comparison of local fallout products with standard source; autoradiography).

Sources of Radioisotope Experiments in High School Chemistry and Physics

Several of the publications in the preceding section can be used in high school chemistry and physics as well as in biology. The following references provide experiments that apply specifically to chemistry and physics.

Chase, Grafton D., and Joseph Rabinowitz, *Principles of Radioisotope Methodology,* Burgess Publishing Co., Minneapolis, Minn., 1963.

Nuclear-Chicago Corporation, *A Collection of Comprehensive Scientific Papers on the Application and Measurement of Radioactivity,* Nuclear-Chicago Corporation, Des Plaines, Ill., 1964.

Nucleonic Corporation of America, *Radioisotope Courses and Experiments for Basic Science and Engineering Curricula,* Nucleonic Corporation of America, Brooklyn, N. Y., 1962.

Picker X-Ray Corporation, *Radioisotope Training Manual, Part II: Experiments,* Nuclear Division, Picker X-Ray Corporation, White Plains, N. Y., 1960.

Radin, Norman (Ed.), *Radioisotope Experiments for the Chemistry Curriculum,* Nuclear-Chicago Corporation, Des Plaines, Ill., 1960.

General Readings in Nuclear Science

The following readings are suggested for the enterprising student who may desire background information on the history and theory of nuclear science as well as an orientation in the broad applications of radioactivity in modern research.

Alexander, Peter, *Atomic Radiation and Life*, 2nd ed., Penguin Books, Inc., Baltimore, Md., 1965.

A Manual of Radioactivity Procedures, National Bureau of Standards, Handbook No. 80, 1961, Available from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.

Andrews, Howard L., *Radiation Biophysics*, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1961.

Asimov, Isaac, *Building Blocks of the Universe*, rev. ed., Abelard-Schuman Limited, New York, 1961.

Asimov, Isaac, *Inside the Atom*, Abelard-Schuman Limited, New York, 1961.

Atomic Radiation, Part I, RCA Service Company, Division of Radio Corporation of America, Camden, N. J., 1961.

Atomic Radiation, Part II, RCA Service Company, Division of Radio Corporation of America, Camden, N. J., 1962.

Bacq, Z. M., and Peter Alexander, *Fundamentals of Radiobiology*, 2nd ed., Pergamon Press Ltd., Oxford, England, 1961.

Boyd, G. A., *Autoradiography in Biology and Medicine*, Academic Press Inc., New York, 1955.

Brownell, Lloyd E., *Radiation Uses in Industry and Science*, U. S. Atomic Energy Commission, Available from Superintendent of Documents, Government Printing Office, Washington, D. C., 1961.

Bush, George L., and Anthony A. Silvidi, *The Atom: A Simplified Description,* A. S. Barnes & Co., New York, 1961.

Calder, Ritchie, *Living with the Atom,* The University of Chicago Press, Chicago, 1962.

Chase, G. D., and J. L. Rabinowitz, *Principles of Radioisotope Methodology,* 2nd ed., Burgess Publishing Co, Minneapolis, Minn., 1962.

Choppin, Gregory R., *Experimental Nuclear Chemistry,* Prentice-Hall, Inc., Englewood Cliffs, N. J., 1961.

Claus, W. D. (Ed.), *Radiation Biology and Medicine,* Addison-Wesley Publishing Company, Inc., Reading, Mass., 1958.

Comar, C. L., *Radioisotopes in Biology and Agriculture,* McGraw-Hill Book Company, Inc., New York, 1955.

Control and Removal of Radioactive Contamination in Laboratories, National Bureau of Standards, Handbook No. 48, 1951, Available from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.

Cronkite, Eugene P., and Victor P. Bond, *Radiation Injury in Man,* Charles C. Thomas, Publisher, Springfield, Ill., 1960.

Faires, R. A., and B. H. Parkes, *Radioisotope Laboratory Techniques,* 2nd ed., Pitman Publishing Corp., New York, 1960.

Fermi, Laura, *The Story of Atomic Energy,* Random House, Inc., New York, 1961.

Ford, Kenneth, *The World of Elementary Particles,* Blaisdell Publishing Co., Inc., New York, 1965.

Frisch, Otto R., *Atomic Physics Today,* Fawcett Publications, Inc., Greenwich, Conn., 1965.

Gamow, George, *The Atom and Its Nucleus,* Prentice-Hall, Inc., Englewood Cliffs, N. J., 1961.

Glassner, Alvin, *Introduction to Nuclear Science,* D. Van Nostrand Company, Inc., Princeton, N. J., 1961.

Glasstone, Samuel, *Sourcebook on Atomic Energy,* 2nd ed., D. Van Nostrand Company, Inc., Princeton, N. J., 1958.

Hecht, Selig, *Explaining the Atom,* Viking Press, Inc., New York, 1960.

Heckman, Harry H., and Paul W. Starring, *Nuclear Physics and the Fundamental Particles*, Holt, Rinehart & Winston, Inc., New York, 1963.

Hill, R. D., *Tracking Down Particles*, W. A. Benjamin, Inc., New York, 1963.

Hoopes, Roy, *A Report on Fallout in Your Food*, New American Library of World Literature, Inc., New York, 1962.

Kamen, Martin D., *A Tracer Experiment*, Holt, Rinehart & Winston, Inc., New York, 1964.

Kamen, Martin D., *Isotopic Tracers in Biology*, 3rd ed., Academic Press Inc., New York, 1957.

Kinsman, Simon, et al. (Eds.), *Radiological Health Handbook*, Public Health Service, U. S. Department of Health, Education, and Welfare, Washington, D. C., 1960, Available from Clearinghouse for Federal Scientific and Technical Information, U. S. Department of Commerce, Springfield, Va.

Lapp, Ralph E., *Roads to Discovery*, Harper & Row, Inc., New York, 1960.

Lapp, Ralph E., and Howard Andrews, *Nuclear Radiation Physics*, 3rd ed., Prentice-Hall, Inc., Englewood Cliffs, N. J., 1963.

Lea, D. E., *Actions of Radiation on Living Cells*, [illegible] ed., Cambridge University Press, London; The Macmillan Company, New York, 1956.

Mann, Martin, *Peacetime Uses of Atomic Energy*, Viking Press, Inc., New York, 1961.

Meyer, Leo, *Atomic Energy in Industry*, American Technical Society, Chicago, 1963.

Overman, Ralph T., *Basic Concepts of Nuclear Chemistry*, Reinhold Publishing Corporation, New York, 1963.

Overman, Ralph T., and Herbert M. Clark, *Radioisotope Techniques*, McGraw-Hill Book Company, Inc., New York, 1960.

Physical Aspects of Irradiation, National Bureau of Standards, Handbook No. 85, 1964, Available from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.

Quimby, Edith, and S. Feitelberg, *Radioactive Isotopes in Medicine and Biology, Vol. I: Basic Physics and Instrumentation*, Lea & Febiger, Philadelphia, 1963.

Renne, Harold S., *How to Detect and Measure Radiation*, Howard W. Sams & Co., Inc., Publishers, Indianapolis, Ind., 1963.

Romer, Alfred, *The Restless Atom*, Doubleday & Co., Inc., Garden City, N. Y., 1960.

Sacks, J., *Atom at Work*, The Ronald Press Company, New York, 1956.

Safe Handling of Radioactive Materials, National Bureau of Standards, Handbook No. 92, 1964, Available from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.

Seaborg, Glenn T., *Man-made Transuranium Elements*, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1963.

Semat, Henry, and Harvey E. White, *Atomic Age Physics*, Holt, Rinehart & Winston, Inc., New York, 1959.

Shilling, Charles Wesley, *Atomic Energy Encyclopedia in the Life Sciences*, W. B. Saunders Company, Philadelphia, 1964.

Shubert, J., and R. E. Lapp, *Radiation: What It Is and How It Affects You*, Viking Press, Inc., New York, 1957.

Thompson, William E., Jr., *Your Future in Nuclear Energy Fields*, Richards Rosen Associates, Inc., New York, 1961.

Thomson, John F., *Radiation Protection in Mammals*, Reinhold Publishing Corporation, New York, 1962.

U. S. Atomic Energy Commission, Division of Isotopes Development, *Special Sources of Information on Isotopes*, USAEC Report TID-4563 (3rd Rev.), Available from USAEC, Division of Technical Information Extension, Oak Ridge, Tenn., 1962.

U. S. Atomic Energy Commission, Division of Technical Information, Understanding the Atom Series, Available from USAEC, Division of Technical Information Extension, Oak Ridge, Tenn.

Accelerators, by William J. Kernan

Atomic Fuel, by John F. Hogerton

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U. S. Atomic Energy Commission, Division of Technical Information, *What's Available in the Atomic Energy Literature*, USAEC Report TID-4550 (11th Rev.), Available from USAEC, Division of Technical Information Extension, Oak Ridge, Tenn., 1966.

Walker, Harold L., *Careers in the Atomic Energy Industry*, Bellman Publishing Co., Cambridge, Mass., 1958.

Wang, C. H., and David L. Willis, *Radiotracer Methodology in Biological Science*, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1965.

Suppliers of Generally Licensed Radioisotopes

The radioisotopes used in the experiments of this bibliography are all generally licensed. For the small quantities required, a specific license from the United States Atomic Energy Commission or from state licensing agencies is not needed. A thorough planning of experiments and the careful application of laboratory techniques are essential; however, elaborate monitoring equipment is not required.

All users of radioisotopes must adhere to regulations concerning radioisotope use and should therefore obtain a copy of the *Code of Federal Regulations,* Title 10—Atomic Energy, Chapter 1, Part 20—Standards for Protection Against Radiation, and Part 30—Licensing of Byproduct Material. Copies may be obtained free of charge from the Division of Materials Licensing, U. S. Atomic Energy Commission, Washington, D. C. 20545. Also, in some states the State Department of Health provides a statement of regulations concerning the use of radioisotopes.

The following firms are some of the commercial suppliers of generally licensed radioisotopes with which the author is familiar. A more extensive list can be found in *The Isotope Index,* James L. Sommerville, Ed., Scientific Equipment Company, Publications Department, P. O. Box 19086, Indianapolis, Indiana 48219, $2.00.

Abbott Laboratories
Radio-Pharmaceuticals
Abbott Park
North Chicago, Ill. 60064

Atomic Corporation of America
7901 San Fernando Road
Sun Valley, Calif. 91352

Cambridge Nuclear Corp.
131 Portland Street
Cambridge, Mass. 02139

ChemTrac Corp.
Radiochemical Division of
Baird-Atomic, Inc.
33 University Road
Cambridge, Mass. 02138

General Radioisotope Processing Corp.
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San Ramon, Calif. 94583

New England Nuclear Corp.
575 Albany Street
Boston, Mass. 02118

Nuclear-Chicago Corporation
333 East Howard Avenue
Des Plaines, Ill. 60018

Nuclear Consultants Corp.
9842 Manchester Road
St. Louis, Mo. 63119

Nuclear Research Chemicals, Inc.
P O. Box 6458
100 North Crystal Lake Drive
Orlando, Fla. 32803

Nuclear Science & Engineering Corp.
P. O. Box 10901
Pittsburgh, Pa. 15236

Nucleonic Corp. of America
196 Degraw Street
Brooklyn, N. Y. 11231

Schwarz Bio-Research, Incorporated
Mountainview Avenue
Orangeburg, N. Y. 10962

Squibb, E. R., & Sons
Radiopharmaceutical Department
Georges Road
New Brunswick, N. J. 08903

Tracerlab Inc.
Technical Products Division
1601 Trapelo Road
Waltham, Mass. 02081

U. S. Nuclear Corp.
P. O. Box 208
Burbank, Calif. 91503

Volk Radiochemical Co.
8260 Elmwood Avenue
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